3.5 Atomic Structure: 1-hour Pack

AQA 8461 · Calculator allowed · about 60 minutes

Total Marks

Name: _____ Date: ____ / ____ / _____

Answer ALL questions. Show all your working.

1 The nucleus of an unstable atom can change to become more stable by emitting radiation.

(a) State what is meant by 'radioactive decay'. **(2)**

(b) State why radioactive decay is described as a random process. **(1)**

(c) Name the three main types of ionising nuclear radiation that can be emitted by unstable nuclei. **(3)**

(Total for Question 1 is 6 marks)

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2 Chlorine has two common isotopes: chlorine-35 and chlorine-37. A neutral chlorine atom has atomic number 17.

(a) Calculate the number of neutrons in chlorine-35. **(1)**

.....

(b) Calculate the number of neutrons in chlorine-37. **(1)**

.....

(Total for Question 2 is 2 marks)

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3 A machine controls the thickness of aluminium foil as it is produced by passing a beam of radiation through the foil and measuring the count rate with a detector on the other side.

(a) Explain why a β source, rather than an α or a γ source, is suitable for this application. **(3)**

(b) Suggest what would happen to the detected count rate if the foil became too thick, and how this reading could be used to control the machine. **(2)**

(Total for Question 3 is 5 marks)

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4 Radioactive isotopes have important uses in medicine. Gamma-emitting isotopes such as technetium-99m are used as tracers to diagnose disease, and γ or β emitters can be used in radiotherapy to treat cancer by destroying tumour cells. However, radioactive sources also carry risks because ionising radiation can damage or kill living cells. Evaluate the use of radioactive sources in medicine, weighing up the benefits against the risks.

(Total for Question 4 is 6 marks)

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5 In a classroom demonstration a teacher places a radioactive source 2.0 m from a detector and measures count rate 200 counts per minute (cpm). The teacher then moves the source to 1.0 m from the detector.

(a) Predict whether the count rate will increase, decrease or stay the same when the source is moved from 2.0 m to 1.0 m. **(1)**

(b) Explain why the count rate changes in that way in terms of distance and detection of particles. **(2)**

(Total for Question 5 is 3 marks)

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6 The early model of the atom described atoms as 'plum pudding', later replaced by Rutherford's nuclear model.

(a) Explain briefly how the α scattering experiment led Rutherford to propose a nuclear model of the atom. **(3)**

(Total for Question 6 is 3 marks)

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7 Explain how the structure of an atom determines its identity, its common isotopes, and how an ion forms. Support your answer with clear reasons and examples.

(Total for Question 7 is 6 marks)

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8 The atomic model changed in the early 20th century as evidence accumulated. A student lists three pieces of evidence: α scattering, line spectra, and charge-to-mass ratio measurements of the electron.

(a) Explain how α scattering provided evidence for a small dense nucleus. **(2)**

(b) Briefly state what line spectra indicate about electron energy levels. **(1)**

(c) State what the measurement of the charge-to-mass ratio of the electron showed about subatomic particles. **(1)**

(Total for Question 8 is 4 marks)

9 Write nuclear equations for the following decay processes. Use element symbols and mass and atomic numbers where appropriate.

(a) 210Po undergoes α decay. Write the nuclear equation. **(2)**

(b) 14C decays by β minus emission. Write the nuclear equation. **(2)**

(Total for Question 9 is 4 marks)

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10 A student used a GM tube to measure the corrected count rate of a radioactive source at 10-minute intervals, as part of a required practical to determine its half-life.
Time (minutes): 0, 10, 20, 30, 40.
Corrected count rate (cpm): 640, 320, 160, 80, 40.

Corrected count rate against time

Time (min)	0	10	20	30	40
Count rate (cpm)	640	320	160	80	40

(a) Explain how these results show the half-life of the source, without needing to plot a graph. **(2)**

(b) State the half-life of the source shown by this data. **(1)**

(c) Suggest one improvement the student could make to increase the reliability of the half-life value obtained. **(2)**

(d) Explain why radioactive decay is described as a random process, and why this means a single count rate reading might not be completely reliable. **(2)**

(Total for Question 10 is 7 marks)

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Mark scheme · 3.5 Atomic Structure: 1-hour Pack

Question 1

(a) the nucleus of an unstable atom breaks down/changes **B1**

(a) and emits radiation (in the form of particles and/or energy) to become more stable, oe **B1**

(a) Answer: The nucleus of an unstable atom breaks down and emits radiation to become more stable.

(b) it is impossible to predict which nucleus in a sample will decay next, or exactly when any particular nucleus will decay, oe **B1**

(b) Answer: It is impossible to predict which nucleus will decay, or when.

(c) α (particle/radiation) **B1**

(c) β (particle/radiation) **B1**

(c) γ (radiation/rays) **B1**

(c) Answer: Alpha, β and γ radiation.

Question 2

(a) 35 - 17 = 18 neutrons **B1**

(a) Answer: 18 neutrons

(b) 37 - 17 = 20 neutrons **B1**

(b) Answer: 20 neutrons

Question 3

(a) an α source would be completely absorbed by the foil (or even the air gap), so no change in count rate could be detected as thickness varies **B1**

(a) a γ source would barely be absorbed by such thin foil, so the count rate would change very little as thickness varies **B1**

(a) a β source is partially absorbed by the foil, so small changes in thickness produce a measurable/detectable change in the count rate, oe **B1**

(a) Answer: Alpha would be completely absorbed by the foil (no useful signal). Gamma would barely be absorbed (little change with thickness). Beta is partially absorbed, so its count rate changes measurably with foil thickness.

(b) the count rate detected would decrease, because more β radiation is absorbed by the thicker foil, oe **B1**

(b) this drop in count rate can be used to automatically adjust the rollers (move them closer together) to reduce the foil thickness back to the correct value, oe **B1**

(b) Answer: The count rate would decrease (more radiation absorbed), which can trigger the rollers to move closer together and reduce the thickness back to the correct value.

Question 4

Level 1 Simple, largely unlinked statements are made about a benefit or a risk of radioactive sources in medicine, with little reference to specific uses or the ionising properties of radiation. **1-2**

Level 2 Some relevant benefits (e.g. diagnosis, destroying cancer cells) and risks (e.g. damage to healthy cells, risk of causing cancer) are given, with partial links between the properties of the radiation used and its medical purpose, but the evaluation is not fully balanced or justified. **3-4**

Level 3 A clear, well-linked evaluation is given that explains why gamma radiation is suitable as a tracer (penetrates the body to be detected externally, does not need to be intensely ionising) and why radiotherapy deliberately uses ionising radiation to kill tumour cells while accepting some damage to nearby healthy cells, and weighs these benefits against risks such as radiation exposure to patients and staff, damage to healthy tissue and the small increased risk of secondary cancers, reaching a justified overall conclusion (e.g. that the benefits generally outweigh the risks when doses are carefully controlled). **5-6**

Indicative content:

- Gamma-emitting tracers are used because gamma radiation penetrates body tissue and can be detected by a scanner outside the body, allowing doctors to see how an organ is functioning without surgery
- A tracer's half-life should be short enough to minimise the time the patient is exposed to radiation, but long enough to allow the scan to be completed
- Radiotherapy uses carefully targeted, ionising radiation (beam or implanted source) to kill cancer cells by damaging their DNA
- Risk: ionising radiation can also damage healthy cells near the tumour, causing side effects, and can increase the small risk of the patient developing a different cancer later
- Risk: staff and other patients need protection (e.g. lead shielding, distance, limited exposure time) to reduce their own radiation dose
- Benefit: early and accurate diagnosis, or successful treatment of cancer, can save lives, and the doses used are carefully calculated and monitored to keep risk as low as reasonably possible
- An overall judgement that, for most patients, the medical benefit outweighs the risk because doses are controlled and monitored, though this must be balanced individually for each patient and use

Question 5

(a) increase cao **B1**

(a) Answer: Increase

(b) states that closer distance means more particles reach the detector per unit time **M1**

(b) because intensity falls with distance so halving distance gives more counts at 1.0 m than at 2.0 m, oe **A1**

(b) Answer: Increase, because moving the source closer means more of the emitted particles reach the detector per minute; intensity falls with distance so halving the distance gives a higher count rate.

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Question 6

(a) states that most α particles passed straight through the foil **M1**

(a) states that some α particles were deflected or scattered at large angles **M1**

(a) concludes that atoms have a small dense positively charged nucleus that caused the deflections, with electrons around it, oe **A1**

(a) Answer: Most α particles passed straight through, but some were strongly deflected; this showed atoms have a small dense positively charged nucleus that deflects particles, with electrons outside.

Question 7

Level 3 Detailed explanation that links atomic structure to identity, isotopes and ion formation. Uses correct examples and shows clear reasoning. **5-6**

Level 2 Partial explanation covering two of the three ideas with some correct reasoning and at least one example. **3-4**

Level 1 Basic statements about atoms with limited or missing links between structure and the three topics; may include factual errors. **1-2**

Indicative content:

- Identity: atomic number equals number of protons; changing protons changes element; example: carbon proton number 6 so element is carbon.
- Isotopes: same atomic number (same protons) but different neutrons; give example such as carbon-12 and carbon-14; explain that isotopes have similar chemical properties but different mass and some are radioactive.
- Ion formation: ions form when atoms lose or gain electrons; losing electrons makes positive ions and gaining makes negative ions; example: sodium atom Na (11 electrons) loses one electron to form Na^+; chloride atom gains one electron to form Cl^-.
- Linking ideas: show how electron arrangement affects chemical behaviour and ion formation; mention conservation of protons when making isotopes and ions.

Question 8

(a) states that most α particles passed through the foil but some were deflected at large angles **M1**

(a) concludes that most of atom is empty space but there is a small, dense, positively charged nucleus that caused large deflections, oe **A1**

(a) Answer: Most α particles passed through indicating mostly empty space; occasional large deflections showed a small dense positive nucleus that repelled some alphas.

(b) that electrons occupy discrete energy levels and emit/absorb photons when moving between levels, oe **B1**

(b) Answer: Electrons occupy discrete energy levels and emit or absorb photons when changing levels.

(c) that electrons are very small, negatively charged particles with a large charge-to-mass ratio, showing atoms have smaller charged parts, oe **B1**

(c) Answer: That electrons are very small, negatively charged particles with a large charge-to-mass ratio, showing atoms have smaller charged parts.

Question 9

(a) shows α particle as 4He (mass 4, atomic 2) and subtracts from parent: 210 -> 206 and atomic number subtracts by 2 **M1**

(a) 210Po -> 206Pb + 4He (or 210 84 Po -> 206 82 Pb + 4 2 He) cao **A1**

(a) Answer: 210 84 Po -> 206 82 Pb + 4 2 He

(b) shows β minus as electron with mass 0 and charge -1 and adjusts atomic number +1 **M1**

(b) 14 6 C -> 14 7 N + 0 -1 e (or 14C -> 14N + β) cao **A1**

(b) Answer: 14 6 C -> 14 7 N + 0 -1 e

Question 10

(a) the count rate halves every 10 minutes throughout the table (640 to 320 to 160 to 80 to 40), oe **B1**

(a) so the half-life can be read directly as the fixed time interval over which the count rate always halves, without needing to plot and interpret a graph **B1**

(a) Answer: The count rate halves every 10 minutes, so the half-life is 10 minutes.

(b) 10 minutes, ft from 19a **B1**

(b) Answer: 10 minutes

(c) valid improvement identified, e.g. repeat the count rate reading at each time interval and take a mean, or take each count over a longer time period **B1**

(c) explanation of how this improves reliability, e.g. reduces the effect of the random/statistical fluctuations in the count rate on the result, oe **B1**

(c) Answer: Repeat each reading (or count for longer at each interval) and take a mean, to reduce the effect of random statistical fluctuation on the result.

(d) it is impossible to predict which individual nucleus will decay, or exactly when, so the number of decays in a given time interval varies naturally from one measurement to the next, oe **B1**

(d) a single reading may therefore be higher or lower than the true average count rate purely by chance, so it may not be a reliable representation of the source's activity, oe **B1**

(d) Answer: Decay is random, so the exact number of counts recorded in a fixed time varies by chance each time; a single reading might be unusually high or low and not reliably represent the true count rate.

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